Investigation of Methods of Disinfection in an All-air System

Jilou Wang
Associate Professor

Zheng Yan
Assistant Engineer

Beijing Institute of Civil Engineering and Architecture
Beijing P.R.China, 100044
Yanzh0990@vip.sina.com

Abstract: The experiment of removing bacteria and indoor air particulates by a bag ventilation filter with synthetic media and an electrostatic filter was carried out, and the effect of killing bacteria by ozone application was also tested. The results show that the two cleaning methods can achieve a 90 percent bacteria killing rate and guarantee a safe and healthy air supply in an all-air system.

Key words: all- air system; air filter; ozone

1. INTRODUCTION

There are more and more attentions to indoor air pollutions recently. The bacteria concentration of supply air will be exceed if air conditioning system is not clean[1]; in the other side, the cross- contamination between different conditioned rooms can let the bacteria and particles diffuse in the whole building in application of air return mode. [2]

Fixing filter and disinfection apparatus for air conditioning system, which includes synthetic-media filter, electrostatic filter, photocatalytic oxidation, ultraviolet disinfection and ozone disinfection, is effective method to avoid the air return pollution. [3]

In this paper, the experiments of removing bacteria and particulates of indoor air by a bag ventilation filter with synthetic media, an electrostatic filter and ozone disinfection was carried out. Bag ventilation filter has ripe design; electrostatic filter can adsorb the bacteria in handling air, so has more effective filter method; ozone disinfection is more effective than ultraviolet disinfection, has short half life and hasn't negative hangover.

2. EXPERIMENTATION

2.1 Experimental Board

Figure 1 shows the air conditioning system in laboratory as experimental board. Average stud of laboratory is 3 m, and the volume of laboratory is 150 m^3. There is an all-air system supplying air in laboratory, which includes fresh air duct and return air duct. For the sake of changing supply air flow rate, Siemens Micromaster 420 frequency converter, which can change the frequency of supply fan in range between 5 -60 Hz, was fixed.

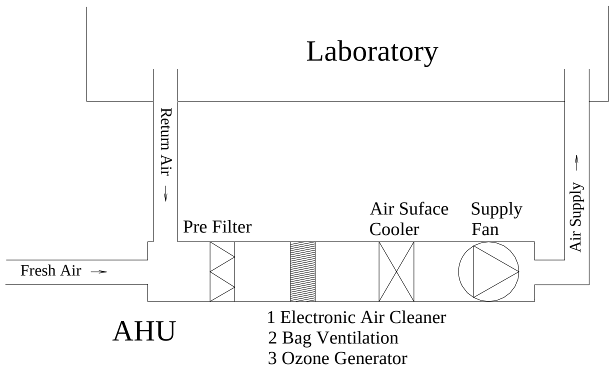

Fig.1 Air conditioning system in laboratory

2.2 Experimental Instruments.

1) CLJ-03A dust particles counter with laser light, which has six channels and can measure particle concentration in the particle size range between 0.3 -10 microns.

2) JWL-IIB202 microorganism monitor, which can collect the bacteria in the air by using striking method.

3) DP1000-I micro manometer.

4) Alnor Compuflow 8585 thermo-anemometers, which measures air flow rate of duct.

5) Z-1200 ozone monitor.

2.3 Filter and Disinfection Apparatus in Experiment

1) Honeywell F58G ducted electronic air cleaner, which has the same filtering principle as electrostatic

filter. It electrizes particles in handling air in ionization area, and absorbs particles in collection area. Figure 2 shows Honeywell F58G.

Fig.2 F58G ducted electronic air cleaner

2) Bag ventilation filter with synthetic media, whose efficiency is equal to Euro-Standard F6.

3) Ozone generator, shown by Figure 3. By using corona generating method, it can generate ozone 6 grams per hour. The rated power of this apparatus is 100 watts.

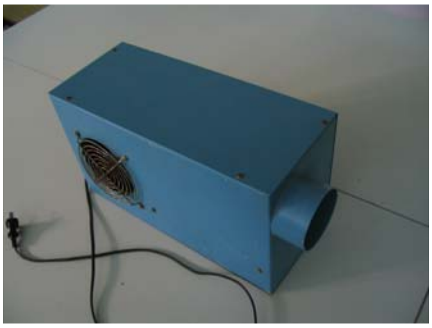

Fig.3 Ozone generator

3. EXPERIMENTAL METHOD AND STEPS

3.1 Testing of Filter Efficiency

In order to get the filter efficiency, particle concentration of the supply air was tested in front of and behind the filter by dust particles counter, in the conditions of different flow rates. The dust source of test is atmosphere dusts.

3.2 Testing of Filter Resistance

In order to get resistance of filter in different flow rates, static pressure in front of and behind the filter was tested by micro manometer.

3.3 Testing of Effect of Filter Removing Indoor Particles and Bacteria.

There is one measuring point in work place of laboratory. Air conditioning system, which had been fixed filter, was running in air circle supply mode and air supply with fresh air mode (percentage of fresh air is 35%). Particle concentration in laboratory was tested per minute by dust particles counter in two ranges (one range is between 0.3 - 3 microns, the other range is lager than 3 microns), in order to analyze the concentration decay along with running time. The bacteria concentration in air was tested by microorganism monitor in 0, 30, 60, 90 minutes after the experiment started. Table 1 shows the contents of this testing in different working conditions.

Tab.1 Working conditions of filter disinfection testing

No	Testing Filter	Air Supply Mode	Supply Air Rate /m^3/h
1	Electronic Air Cleaner	Air Circle Supply	1127
2	Electronic Air Cleaner	Air Circle Supply	1545
3	Electronic Air Cleaner	Air Circle Supply	1881
4	Bag Ventilation Filter	Air Circle Supply	1127
5	Bag Ventilation Filter	Air Circle Supply	1545
6	Bag Ventilation Filter	Air Circle Supply	1881
7	Electronic Air Cleaner	Air Supply with Fresh Air	1545
8	Electronic Air Cleaner	Air Supply with Fresh Air	1881
9	Electronic Air Cleaner	Air Supply with Fresh Air	2228
10	Bag Ventilation Filter	Air Supply with Fresh Air	1545
11	Bag Ventilation Filter	Air Supply with Fresh Air	1881
12	Bag Ventilation Filter	Air Supply with Fresh Air	2228

3.4 Tests of Effect of Ozone Disinfection

The ozone generator was laid in air handling unit. Before experiment, five measure points was laid out in laboratory work place. The settlement bacteria was sampled in 10 minutes, and the pelagic bacteria in the air was sampled by the microorganism monitor. Ozone monitor, which tested indoor ozone concentration in the experiment, was laid in the middle point of laboratory. In experiment, the ozone generator was running during a given time when there was no person in laboratory. When ozone concentration decreased to 0.08ppm after ozone generator stopped, the experiment was finished, and bacteria concentration in laboratory was tested.

Nine tests were carried out in different working conditions, which included duration of ozone generating, the relative humidity of laboratory and supply air rate. The contents of this testing is shown in Table 2.

Tab.2 Working conditions of ozone disinfection testing

No	Indoor Relative Humidity /%	Duration of Ozone Generating /min	Supply Air Rate /m3/h
1	37	60	2130
2	37	90	2130
3	37	120	2130
4	37	30	2130
5	37	60	1130
6	57	60	1130
7	57	60	2130
8	57	30	2130
9	57	90	2130

4. TESTING RESULTS AND ANALYSIS

4.1 Results of Filter Efficiency Testing

The results are shown by Figures 4 and 5. It showed that F58G ducted electronic air cleaner have the higher efficiency than bag ventilation filter with synthetic media, especially to the smaller particle less than 3 microns. It can be analyzed that the method of removing particle by electrostatic absorbing is more effect than by traditional synthetic media according to inertia and diffusion principle.

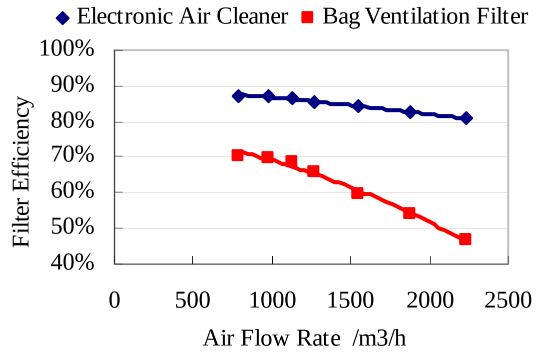

Fig.4 Filter efficiency of particle size in 0.3-3 microns

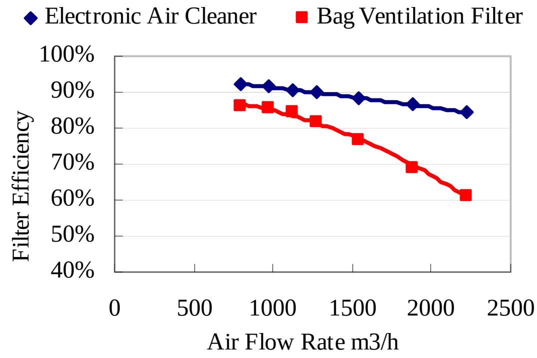

Fig.5 Filter efficiency of particle size upon 3 microns

4.2 The Effect of Two Filters' Removing Particles and Bacteria

When the particles were arrested by the filter, the bacteria and virus in the air lost their carrier of nutrition and decreased accordingly. So by measuring the length of duration from common statue to indoor particle concentration decreased to 10 percent, rate of bacteria and virus deceasing to the safe statue can be reflected. Figure 6 and figure 7 show that the rate of filter removing particles can be improved by means of increasing the supply air flow rate. In the range of particle size between 0.3 and 3 microns, duration of removing particles by F58G ducted electronic air cleaner was obviously lower than by bag ventilation filter with synthetic media, which shows the excellent effect on removing the small particles by electronic air cleaner.

Figure 8 and figure 9 show the indoor bacteria clearance rate of the two filters, which had been working for 90 minutes. The bacteria clearance rate of electronic air cleaner can reach 93 - 97 percent, and is evidently better than bag ventilation filter. Electronic air cleaner shows excellent disinfection effect in this

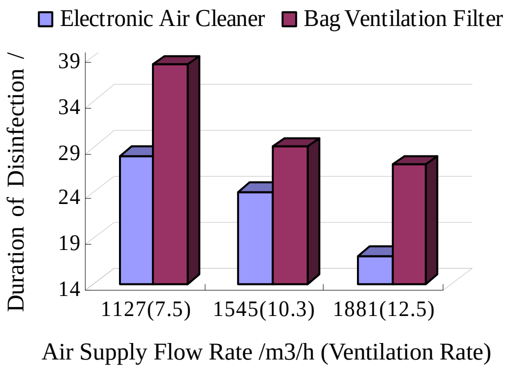

Fig.6 Duration of disinfection (particle size 0.3-3 microns)

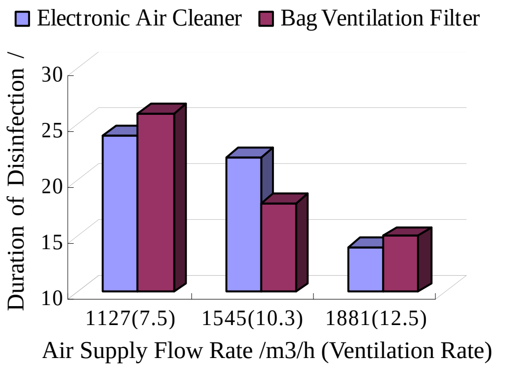

Fig7 Duration of disinfection (particle size upon 3 microns)

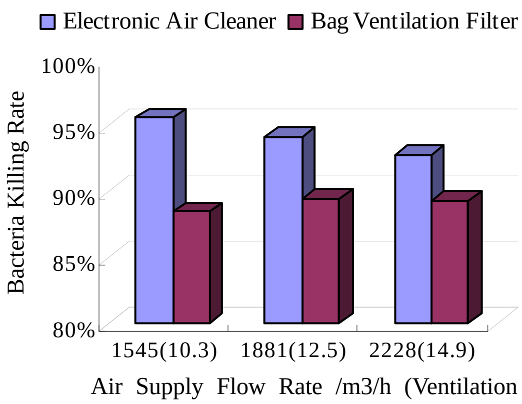

Fig.8 Bacteria killing rate of the two filters in air supply with fresh air conditions

testing.

4.3 Analysis of Resistance and Energy Consumption of the Two Filters

Figure 10 shows resistance of the two filters varying with air supply flow rate. Resistance of electronic air cleaner is markedly lower than bag

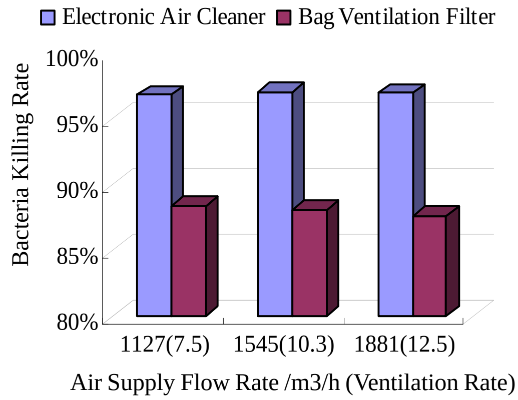

Fig.9 Bacteria killing rate of the two filters in air circle supply conditions

ventilation filter. The reason is that resistance of electronic air cleaner only includes the inlet and outlet pressure drop and the pressure drop arose by the air passed the electrode plate. The data of flow rate and resistance testing results was linear regressed in least square method. The results are shown as follow:

Resistance of electronic air cleaner

$$\Delta P = 2\times10^{-6}V_1^{2.02} \quad (1)$$

Resistance of bag ventilation filter

$$\Delta P = 0.0104V_2^{1.11} \quad (2)$$

Where V_1 and V_2 are the air supply flow rate.

Then base on (1) and (2), the electric power and all-year energy consumption of air supply fan increased as a result of fixing filter can be calculated, which is shown in Table 3.

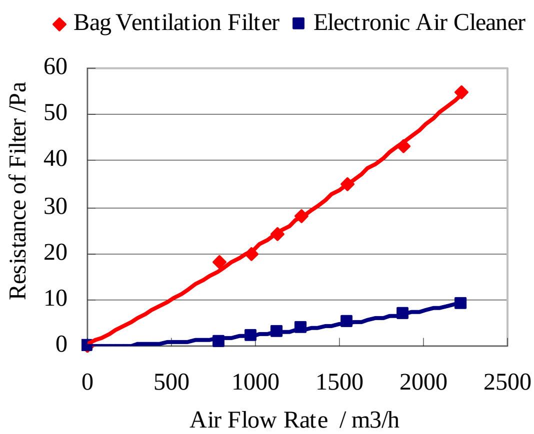

Fig.10 Resistance of the two filters in different air flow rate

Tab.3 Energy consumption of the two filters

Air Flow Rate /m3/h	Power Consumption of Bag Ventilation Filter /W	Power Consumption of Electronic Air Cleaner /W	Energy Consumption Difference of the Two Filters in a Year /kWh
2000	38	38	0
2200	47	41	50
2400	52	43	82
2600	66	47	166
2800	72	50	194
3000	90	56	293
3200	96	60	319

4.4 Analysis of the Effect of Ozone Disinfection

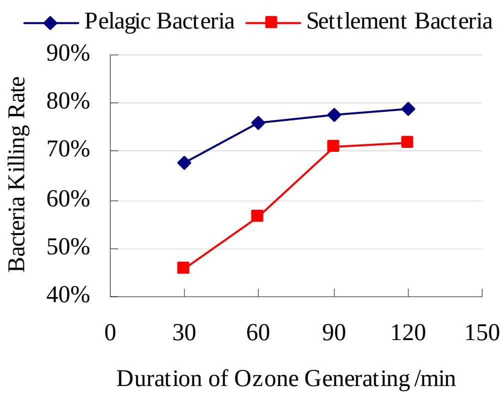

Fig.11 Bacteria killing rate of ozone disinfection in 37% humidity conditions

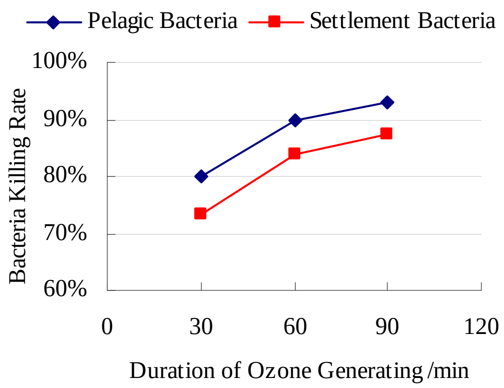

Fig.12 Bacteria killing rate of ozone disinfection in 57% humidity conditions

Figure 11 and figure 12 show indoor bacteria clearance rate of ozone disinfection in different working conditions. As indoor humidity was constant, the effect of removing bacteria got better with duration of ozone generating increasing, especially duration of generating between 30-60 minutes.

Indoor humidity had marked influence on bacteria clearance rate. The bacteria clearance rate can reach 90 percent when ozone generator was working for upon 60 minutes, in the conditions of 57 percent indoor humidity. When indoor humidity decreased to 37 percent, the bacteria clearance rate was below 80 percent, even if ozone generator was working for 120 minutes.

Table 4 shows the bacteria clearance rate in tests 1, 5, 6, 7, which were in different working conditions of humidity and supply air rate. The four group data were analyzed in two dimensional variance method. It was found that indoor humidity had marked influence on the bacteria clearance rate, and supply air rate had little.

Tab.4 Influence of supply air rate and relative humidity on ozone disinfection

Indoor Relative Humidity	Circle Supply Air Rate /m3/h	
	1130	2130
37%	74.34%	75.86%
57%	90.01%	89.80%

4.5 Analysis of Factor in Decay Rate of Ozone Concentration

Ozone concentration decreased gradually when ozone generator stopped, as a result of surface's absorption of ozone in laboratory. Figure 13 shows duration of ozone concentration decreasing to maximum allowable indoor ozone concentration (16 mg/m^3) in different working conditions. Absorption capability of surface in laboratory receded with the experiment carrying on. Meanwhile, the decay rate of ozone concentration in working conditions 5 and 6 (with lower supply air rate) is markedly lower than ones in other conditions.

5. CONCLUSION

1) The bacteria clearance rate can reach 93 percent when electronic air cleaner was working for

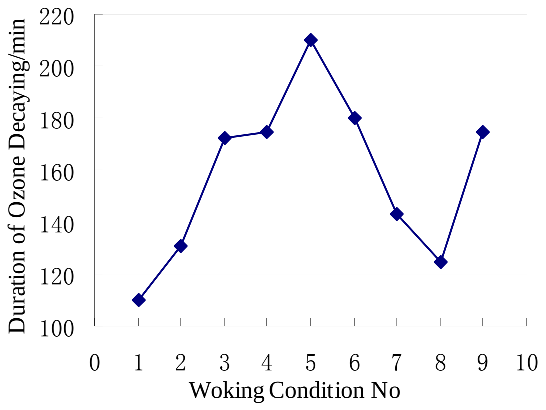

Fig.13 Duration of ozone concentration decreasing to criteria in different working conditions

about 90 minutes, which was markedly higher than the bacteria clearance rate of bag ventilation filter, so electronic air cleaner can satisfy air supply in safe. Duration of disinfection can be decreased when ventilation rate increase.

2) The resistance of electronic air cleaner is extremely low, so the energy consumption is markedly lower than bag ventilation filter.

3) The bacteria clearance rate of ozone disinfection can reach upon 90 percent, when indoor humidity is restricted from 50 percent to 60 percent. It is not suggested that ozone disinfection is used in the conditions of low humidity (below 40 percent).

4) The change of the bacteria clearance rate is small when duration of ozone disinfection extends from 60 to 90 minutes, so it isn't suggested that ozone generator work for upon 90 minutes. Increasing supply air rate can elevate the decay rate of concentration ozone, so it is suggested to increase supply air rate in order to make ozone concentration of disinfecting room reach to maximum allowable indoor ozone concentration in a shot time.

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